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SEARCH FOR FLOW IN THE REACTION Ar + Pb

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Search for Flow in the Reaction Ar + Pb

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Interactions between Ar projectiles and lead are studied in terms of global observables. The Streamer Chamber at the Berkeley BEVALAC was used to record all charged particles produced in collisions between 0.8 GeV/u Ar projectiles with a Pb_3O_4 target. A hardware trigger selected central collisions with Pb nuclei corresponding to a trigger cross section of 1 barn. In a geometrical picture this is equivalent to an impact parameter range of 0–5 fm.

Three views of the Streamer Chamber pictures were recorded on film. All visible tracks were measured on three views and reconstructed in space. Particle identification and separation was achieved by visual inspection of track granularity and by kinematical cuts. Five hundred events have been analyzed so far. Significant experimental biases were found only for particles around target rapidity, where absorption in the target, proton/deuteron ambiguities, and Streamer Chamber inefficiencies are important. Therefore, further analysis was restricted to the particles emerging in the forward direction in the event participant center-of-mass system, computed event by event from only those particles having transverse momenta above 270 MeV/c (see ref. 1). The experimental data were compared to 400 events generated by the intranuclear cascade code of Cugnon et al.[2] in the same impact parameter range as selected by the hardware trigger. In addition, we compare our data to events generated by a Monte Carlo program using an isotropic angular distribution, the same mean multiplicity ($\langle M \rangle = 48$) and the same slope parameter for the energy spectrum ($E_0 = 110$ MeV) as observed in the data. The experimental inefficiencies were folded into the cascade events as well as into the isotropic Monte Carlo events.

The total baryonic transverse energy in the forward hemisphere of each event ($E_t = \sum_{i=1}^{N} \sqrt{p_{t_i}^2 + M_i^2} - M_i$, N = Number of baryons in the event) was used to define subsamples of events corresponding to different impact parameter (b) ranges. Figure 1 shows the correlation between the total transverse energy and b as determined from the cascade events.

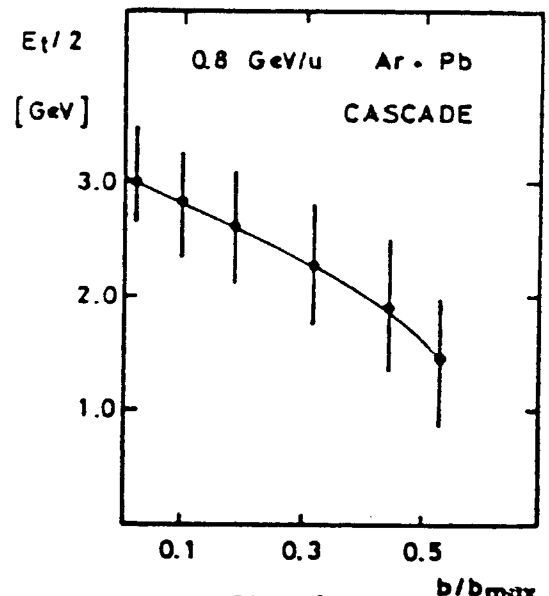

Fig. 1

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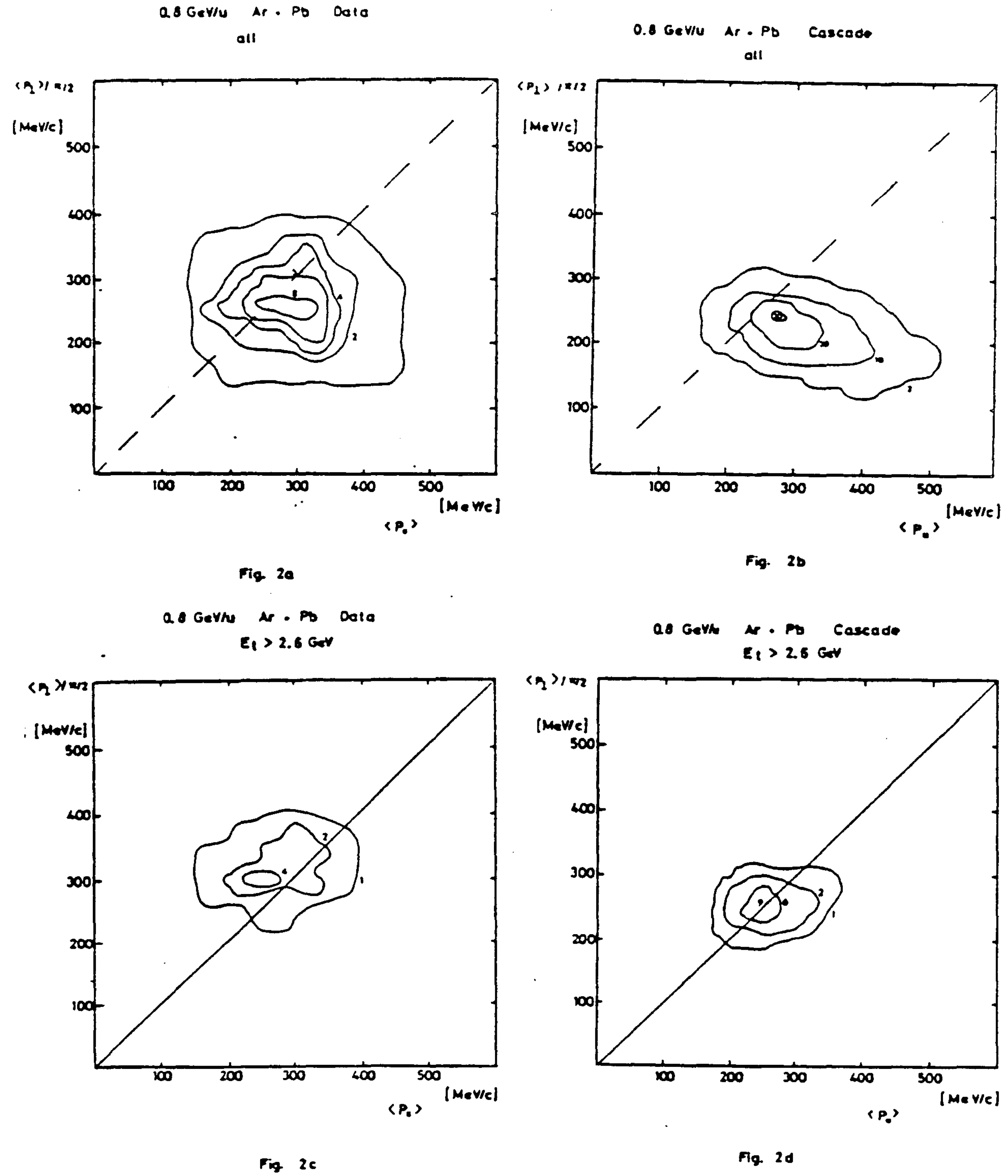

Fig. 2. Average transverse momentum versus average longitudinal momentum per event for exp. data (a+c) and cascade events (b+d) with and without a cut in the total transverse energy measured per event.

In Fig. 2 contour plots of the mean longitudinal ($p_{||}$) versus mean transverse (p_t) momentum per event[3] are presented for both the experimental data and the cascade events, together with subsamples selected for high E_t ($E_t > 2.6$ GeV, i.e., small impact parameter). The cascade events have a significantly higher fraction of events with rather high $p_{||}$. For high E_t ($E_t > 2.6$ GeV, i.e., small impact parameters) both data sets are rather isotropic and centered around the symmetry line. The slight excess in P_t for the data is due to the bias introduced by the E_t selection since it is also seen (not shown here) in the isotropic Monte Carlo events.

Differences between data and cascade can be analyzed in more detail by studying the E_t-dependence of the deflection angle and aspect ratio of the momentum flux tensor.[4] Since b is an a priori unmeasurable quantity we use instead the total transverse energy and determine the bias introduced by this selection criterium with cascade generated events.

The histograms in Fig. 3 show the angular distribution of the main axis of the momentum tensor with respect to the beam direction for the data and cascade events. For high E_t the data show an isotropic distribution whereas the cascade events are still dominated by rather small deflection angles.

A more detailed evaluation of this difference is obtained by the following method:[5] the azimuthal orientation of the main axis of the momentum flux tensor is computed for each event; then each event is rotated around the beam such that the momentum tensor has the same azimuthal angle for all events; finally, for each subsample of events, corresponding to different E_t intervals, a single momentum tensor (formed by the superimposed events) is computed, thus eliminating fluctuations caused by the limited number of particles in a single event.

In Fig. 4 the perpendicular component of the momentum within the reaction plane (defined as the plane spanned by the beam and the main axis of the flux tensor) after the rotation and summation as described above is plotted the parallel momentum component vs $p_{||}$ for a subsample of events with $E_t < 2.6$ GeV in a linear plot. The numbers at the contour lines indicate the number of particles. A finite deflection angle can be observed. For comparison the component of p perpendicular to the reaction plane is also plotted. The distribution is symmetric with respect to the beam axis as it should be.

Figure 5 summarizes the result of this analysis. The clear difference in the E_t-dependence of θ between data and cascade events (Fig. 5a) emphasizes the earlier finding of an excess in the deflection of the data as compared to the cascade events. The deflection angles for the isotropic Monte Carlo events are consistently higher than the data. The aspect ratio R_{32} (Fig. 5b) as derived from the latter event sample varies with E_t as expected from the θ behavior: elongation of the momentum tensor for small deflection angles and shapes close to spherical for large angles, which is consistent with a zero deflection angle of an undistorted momentum tensor.[5] The aspect ratios for the experimental data samples indicate near-spherical shapes for the higher E_ts by comparing it to the isotropic distribution, which shows no dependence on E_t. The data indicate a higher

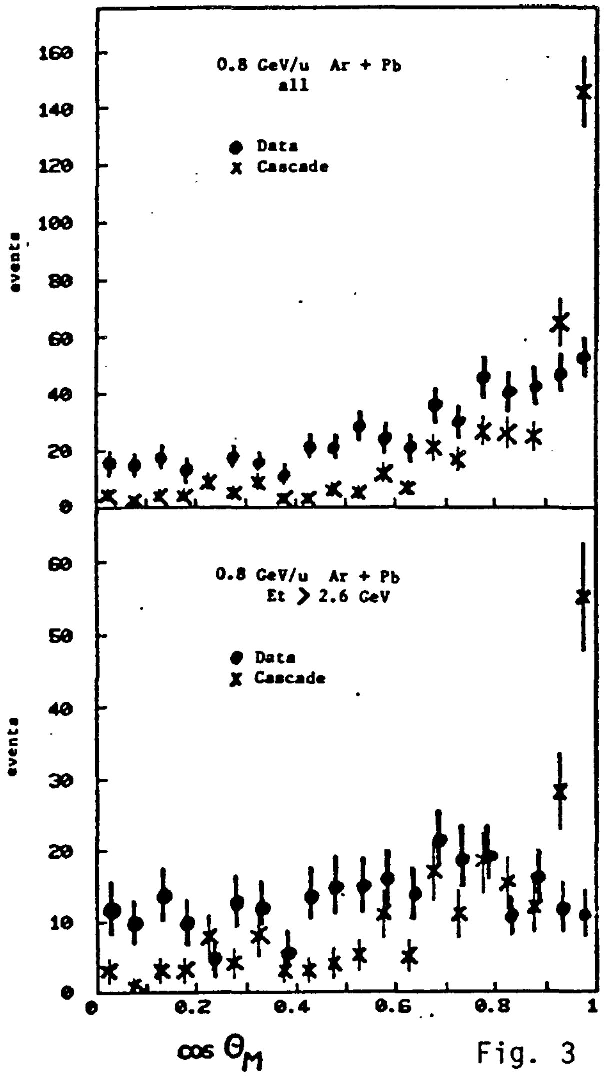

Fig. 3

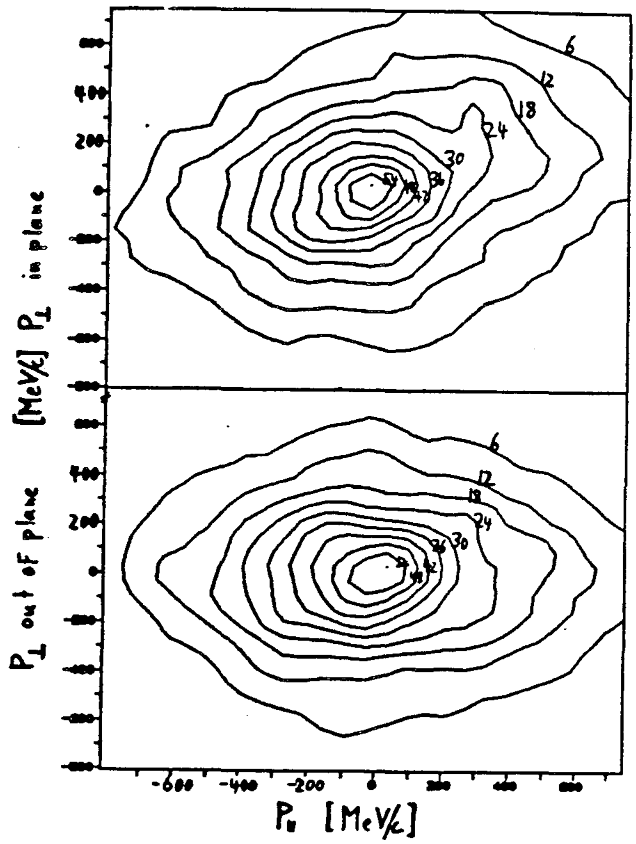

Fig. 4

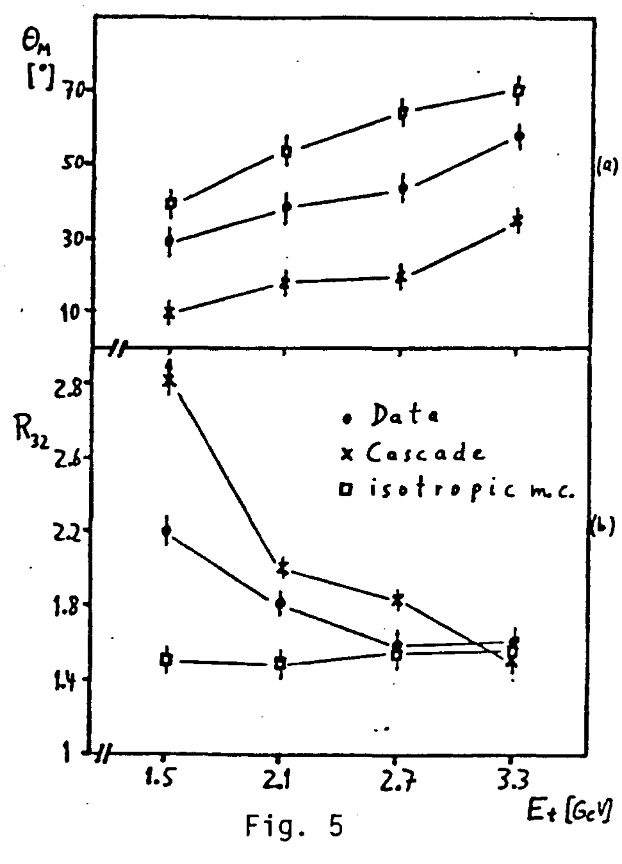

Fig. 5

degree of thermalization than the cascade predicts. The comparison to the isotropic Monte Carlo, on the other hand, indicates a significant deviation from simple thermal behavior. Conclusions about the existence of a bounce-off effect as predicted by hydrodynamical models[6], however, are only possible if detailed predictions are subjected to the same analysis procedures as the experimental data such that systematic biases introduced by these procedures are the same for the model predictions and the data.

We conclude that our experimental data cannot be described satisfactorily by the intranuclear cascade of Cugnon et al. The deviations from the cascade could point towards hydrodynamical flow. However, this can only be verified after the hydrodynamical models are modified such as to be directly comparable to exclusive data.

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